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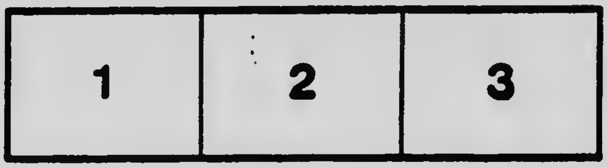

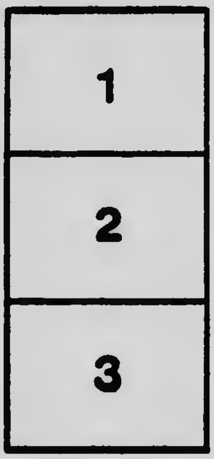

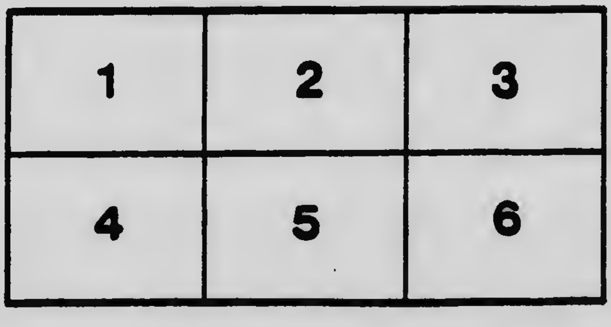

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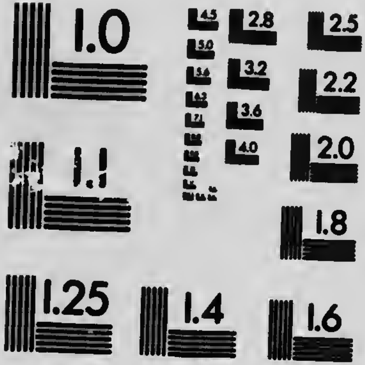

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"Immediately you say, 'I never saw the flash spread out like that, either on the earth or in the cloud.'"—Page 23.

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BULLETIN 220] [MARCH, 1914.

Ontario Department of Agriculture

ONTARIO AGRICULTURAL COLLEGE

Lightning Rods

W. H. Day

"Lightning Rods! Are They any Good?"

Hundreds of times during the past thirteen years this question has been put to the instructors of the Department of Physics. Hundreds of times we have answered "Certainly," only to be immediately confronted with the logical sequent "How do you know?" Until a year ago our chief reason was "Because science says so," but to the farmer that reason has seldom carried conviction, not because he doubted our word particularly, but because he is accustomed to dealing with individual concrete examples, and he has sometime or other known or heard of a "rodded" building having been burned, and with him this one example carried more weight than the teachings of science, no matter how imperfectly the rodding may have been done.

To-day, however, we are no longer dependent upon science alone for our answer, to-day we know from experience that lightning rods, properly installed, are almost absolute protection. Out of every thousand dollars worth of damage done to unrodded buildings by lightning nine hundred and ninety-nine dollars worth would be saved if those buildings were properly rodded! A pretty strong statement, you say. We realize that it is strong. It has taken thirteen years of investigation to compile the data upon which that statement is founded.

Away back in 1901, when Prof. J. B. Reynolds was head of the Department of English and Physics, he began to investigate the efficiency of lightning rods. Five years later, when two departments were formed of one and he chose the Department of English, leaving the writer the Department of Physics, the writer thought he could not do better than continue the work so ably begun. To-day after eight years' further study added to the five we have the problem solved.

Lightning Rods Save Buildings if Struck.

The first question we asked ourselves was this: "If a rodded building is struck, is it as likely to be burned as an unrodded one which is struck?" Reports were received from a number of selected observers in the various counties, also from insurance companies, but a still greater number were clipped from the daily and weekly papers, and in all cases where the owner's address was learned he was written to for a personal report. In the ten years from 1901 to 1910 reports were received covering 599 buildings that were struck by lightning. Of these

317 were burned, or 53.6 per cent. This percentage is higher than obtains generally, because most of our reports originated in the newspapers, and naturally it is chiefly the severe strokes that are thus reported. Amongst that 599 there were only 18 rodded buildings, and of these only three were burned, which is **one in six or 16.6 per cent., as against 53.6.** Hence we concluded that an unrodded building if struck is more than three times as likely to be burned as a rodded one. This is the sum total of the results of our first ten years' study of this subject. As there seemed to be no object in pursuing this phase further, the original line of investigation was discontinued.

On the three rodded buildings that were burned the rods were reported in good repair, but whether the rodding was correctly done we had no means of determining.

Do Lightning Rods Prevent Strokes?

But as early as 1906 we had begun to enquire whether lightning rods hadn't a greater function to perform than save buildings that are struck. We had begun to ask ourselves whether lightning rods do not actually prevent many buildings from being struck! At first thought this looks preposterous, but seemingly preposterous things sometimes turn out real and contain great truths.

But how could we determine whether rods prevent buildings from being struck? If 1,000 rodded buildings escaped damage during a storm, how could we ascertain whether some of them would have been damaged if not rodded? We knew that amongst 599 buildings that were struck there were only 18 rodded ones, which is just 3 per cent. If we knew what percentage of farm buildings in Ontario were rodded that would settle the question. If rods neither prevent nor induce strokes then the percentage of rodded buildings amongst those struck should be just the same as the percentage of rodded buildings in Ontario. If the rods cause strokes then proportionally more rodded ones would be struck than unrodded, but if they prevent strokes, then proportionally less.

Clues That Failed.

To determine what percentage of Ontario buildings are rodded we first endeavored to have the township assessors make a record regarding the buildings on each farm and to have them give a return showing the result. In this we failed. We approached the inspector of insurance with a view to having him make a regulation requiring fire insurance companies to report in every application whether the buildings insured were rodded or not. Again we were disappointed. We thought of endeavouring to have the census enumerators ascertain the number of rodded and unrodded buildings, but this seemed impracticable. We wrote every insurance company doing business in Ontario, about one hundred and forty in all, but they were unable to tell us whether the buildings in their risks were rodded or not.

However, writing the insurance companies was the beginning of the solution. It drew their attention to our work. Early in 1912 the writer accepted an invitation to address the Mutual Fire Underwriters' Association on the subject of Lightning Rods. After dealing with the subject from a scientific standpoint and giving the result already noted of our ten years' investigations along the practical side, the writer laid before the members of the Association the important question as to whether rods actually prevent strokes from occurring, and asked their co-operation in answering it.

A few weeks later we wrote to all the Mutual Companies doing business in Ontario, enclosing a card for reply asking whether they would co-operate with us, and suggesting that if they were prepared to do so they should put a question on their application form asking whether the buildings were rodded. We received favorable replies from thirty-eight companies. In the beginning of December we sent out report forms to be filled by them. Eighteen of them kept a special record of all business from July 1st, 1912, and reported results to us.

IN ONTARIO EFFICIENCY OF RODS IN 1912 WAS 94½ PER CENT.

From the reports of these eighteen companies, covering more than one-quarter of the Province, it was found that in every 200 farm buildings insured, 42 were rodded, which is 21 per cent., but out of every 200 farm buildings struck by lightning only 3 were rodded—we should have expected 42 if the rods were no good.*

Or stating it in another way, in every 7,000 *unrodded* farm buildings insured by these companies, 37 were struck by lightning, of which several were burned; but out of every 7,000 *rodded* ones insured, only 2 were struck (and damaged only)—we should have expected 37 if the rods were no good, hence, in Ontario as rods are installed, an unrodded building is 18½ times as likely to be struck as a rodded one is. These results cover all kinds of rods used in Ontario and doubtless include some improper rodding. To prevent damage in 35 cases out of an expectancy of 37 means an efficiency of 94½ per cent.

This result was almost astounding. From scientific considerations we were led to believe that rods must prevent strokes, but we were not prepared for such a sweeping result as this. But you say, "This is only one year's reports, and another year might give the very opposite result."

EFFICIENCY OF RODS IN ONTARIO IN 1913 WAS 92 PER CENT.

During 1913 the insurance companies continued their most valuable co-operation. Forty of them kept special records for us, sixteen being able to give us reports complete in every particular. They represented twelve different counties, and of the buildings insured by them 26.2 per cent. were reported as rodded, showing an increase since last year of 5.2 per cent. The total number of claims paid for lightning damage to buildings was 193, of which 36 were burned, amounting in all to $40,904.53. If the rods had no effect—good or bad—we would have expected 26.2 per cent. of the strokes and damage would have been on rodded buildings, which would mean 50 strokes and $10,715.98, while as a matter of fact the number of strokes to rodded buildings was only 8, and the damage only $57.64, a saving of $10,658.34. To save this amount out of an expectancy of $10,715.98 shows an efficiency of 99.5 per cent.

Of the other twenty-four companies, fifteen were located in the counties above referred to and nine in other counties, in some of which the percentage of rodded buildings is exceptionally high, a fact which we know by personal inspection, so we may safely say that in the whole forty companies the rodded buildings total 26.2 per cent. or more.

***NOTE:** If the efficiency be calculated from these figures it will not agree exactly with that in the succeeding paragraph. This is because the actual percentage was not exactly 21, but that was the nearest whole number—we could not have a fraction of a building struck.

In the reports of the twenty-four companies we find records of two rodded buildings which were burned, one owned by Mr. Harold Currie, of Strathroy, the other by Mr. Murdock Kerr, Embro. Neither of these buildings was rodded according to standard specifications, the former being particularly defective. It is dealt with in detail on page 34. This building would undoubtedly have been saved if properly rodded. Mr. Kerr's rodding was defective in two regards: first, the systems on the main barn and straw barn were not connected, and, secondly, the ground-rods were down only about 3½ to 4 feet, but they were moist when pulled out for examination. Whether the defects were responsible for the fire we have not been able to determine. The bolt was of the ball type, a ball of fire about as large as a man's head coming straight down and hitting the straw barn.

Taking the whole forty companies together, there were 621 lightning damages totalling $113,459.89. 110 of these buildings were burned. We should have expected 26.2 per cent. of the strokes and damage to be on rodded buildings. This would have given 163 strokes and a loss of $29,726.49. As a matter of fact, only 16 rodded buildings were struck and the loss was $3,917.09, so the rods saved $25,809.40, out of an expected loss of $29,726.49, showing an efficiency of 86.8 per cent. Since Mr. Currie's fire was directly due to the absence of ground-rods at a vital point, it seems only fair to consider this barn as not rodded. If this is done the efficiency of the rods in 1913 would be 92.0 per cent.

Perhaps some may reply: "But maybe those rodded buildings expected to be struck were actually struck, and the rods carried off the strokes harmlessly and so the insurance companies, having no claim to pay, have no record of those strokes." If any take this ground, well and good, because it is an admission that the rods in one way or another brought about the desired result, viz., to save the buildings from damage by lightning.

It may be well, however, to remark that in all probability there is some ground for the objection. Probably more than two of the 37 rodded buildings expected to be struck in 1912 were actually struck, and of those expected to be struck in 1913, probably more than 16 were actually struck, and the rods carried off the current without damage, indeed without any trace of the strokes remaining to show that they ever occurred. The exact comparative value of the *saving* and *preventive* functions of rods we are not able to determine, but scientific considerations now lead us to conclude that the preventive function is by far the more important. As the teachings of science regarding the general value of rods have been so strongly confirmed by practical experience, we may with confidence accept the dictum of science when it says that the *chief* function of rods is to prevent strokes from occurring.

For those who want reports over a longer period of years we have them. During these Ontario investigations our attention had been drawn to Iowa and Michigan, where it was reported some advanced work in rodding had been done. Consequently in September, 1913, by the kindness of the Hon. Mr. Duff, the writer was enabled to visit these States and examine conditions at first hand.

IN IOWA LIGHTNING RODS SHOW AN EFFICIENCY OF 98.7 PER CENT.

In Iowa some valuable data were available. For the eight years 1905-1912 inclusive, a large number of insurance companies doing farm business only have reported the percentage of rodded buildings covered by their risks, and also the **claims paid on rodded and unrodded buildings. The highest number of com-**

panies reporting in any one year was 68 and the lowest 46, the average being 55. These companies report that about 50 per cent. of all their risks are rodded. From the reports the following facts are gleaned:

The total lightning claims paid by all these companies for the whole eight years on *rodded* buildings was only $4,464.30, which is an average of $10.15 per company per year. On *unrodded* buildings, however, they paid lightning claims amounting to the large sum of $341,065.32, which is an average of $775.15 per company per year—and the number of unrodded buildings insured was the same as the number of rodded ones. Comparing $775.15 with $10.15 we see that for every $1 paid on rodded buildings $76 was paid on unrodded ones, or the rods save $75 out of an expected loss of $76, if the buildings had not been rodded. This shows an efficiency of 98.7 per cent. It is probable that some improper rodding is included, as the rods were not subject to inspection.

The case is not yet complete, however—in both Ontario and Iowa the reports cover some defective rodding. The true efficiency of lightning rods can only be determined when we consider a large number of properly rodded buildings.

INSPECTED RODS IN MICHIGAN SHOW AN EFFICIENCY OF 99.9 PER CENT.

In Michigan the writer was fortunate enough to procure such a report. The Farmers' Mutual Lightning Protected Insurance Company of Michigan, as its name implies, insures only rodded buildings, and that only after the Company's inspectors have carefully examined the rodding and approved of it. During 1909-1912, inclusive, in a business which for the four years totalled $55,172,075 risk, this company paid only $32 for damage to buildings by lightning, in three small claims all traceable to defects in rodding which were overlooked by the Company's inspector.

The Patrons' Mutual Fire Insurance Co. which also does business all over the State of Michigan insures both rodded and unrodded buildings. In the same four years, [illegible] a total risk of $59,567,272 this company paid lightning damage on buildings to the extent of $32,268.78, which is 1,008 times as much as the protected company paid. In conversation the Secretary of the Patrons' Company said that in eleven years they had only had three small claims for lightning damage on rodded buildings, all the rest of their lightning damage being on unrodded ones. They report 20 per cent. of their risks rodded. Deducting these rodded risks we see that the $32,269 damage occurred on unrodded risks amounting to $47,753,818. At this rate the loss on $55,172,075 of unrodded risks, the same risk as the Protected Company had, would be $37,282, which is 1,168 times as great as the loss on the same amount of properly rodded risks. Thus we see that when the damage to properly rodded buildings amounts to $1, the damage to unrodded ones amounts to $1,168, or in other words, rods save $1,167 out of an expected loss of $1,168, indicating an efficiency of 99.91 per cent., or a saving of $999.10 out of an expected loss of $1,000, thus substantiating the claim made on page 1.

INSURANCE ASSESSMENTS FAVOR RODDED BUILDINGS.

The Protected Mutual began business in October, 1908. Its risks now total $35,000,000, while the Patrons' Mutual in the same time has only increased from $12,000,000 to $19,000,000. So phenomenal has been the success of the Protected Company that it began to draw members rapidly from the other companies. To them this meant ultimate death, so some of them began to carry their rodded and unrodded buildings in separate classes, *each class being assessed for its own losses*, and now nearly every mutual insurance company in the State of Michigan is carrying rodded and unrodded classes, or preparing to do so. The Patrons' Mutual referred to above has been doing so for five years, and its assessments per $1,000 of . have been as follows:

Year	Assessment per $1,000 of Risk	
	Unrodded	Rodded
1909	$2 50	$1 50
1910	3 33	2 50
1911	2 50	1 87½
1912	3 33	2 00
1913	3 33	2 00

During the same five years the assessments of the Protected Company have been:

Year	Assessment per $1,000 of Risk
1909 } 1910 } Together	$2 00
1911	1 80
1912	1 20
1913	2 00

IOWA PROTECTED MUTUAL.

In Iowa there is also a Protected Company, insuring only rodded buildings. The president, Mr. C. N. Doane, Newton, Iowa, is also president of the Mutual Fire and Tornado Association, insuring in the same vicinity as the Protected Company, and taking both rodded and unrodded risks. In six years this Iowa Protected Mutual has not had a claim due to lightning damage to a rodded building or stock in building. Its total assessment per $1,000 for the last five years has been $8.00, while in the Fire and Tornado the total assessment for the same period has been $14.50, a difference of 44.8 per cent. in favour of the Protected Company.

MICHIGAN INSURANCE RATES AVERAGE 36½ PER CENT. CHEAPER ON RODDED BUILDINGS.

While in Michigan the writer spent two days at Lansing in the Department of Insurance examining the original reports of ten different companies including the two above mentioned and compiling data therefrom. Previous to 1913 five of them were carrying both rodded and unrodded classes. I find the average assessment by these five companies on unrodded buildings is $2.96 per $1,000 of risk, while the average on their rodded buildings is $1.89, showing a difference of $1.07 per $1,000 in favour of the rodded buildings. If we calculate that difference in percentage we find that the assessment on rodded buildings is 36½ per cent. less than on unrodded ones. Or taking the rodded assessment as the standard, then the assessment on the unrodded ones is 56.6 per cent. greater than on the rodded ones. Now this is not theory or science—it is the practical experience of cool-headed insurance men and cautious farmers in mutual insurance companies, where the assessment is in direct proportion to the losses incurred. This is the protective value of lightning rods reduced to dollars and cents in insurance rates. Insurance men the world over cannot ignore the experience of the Michigan Companies. Farmers the world over should profit from the lessons taught by the Michigan farmers.

Being now assured that lightning rods are of high protective value, our next logical enquiry would be: "When is a building properly rodded?" Before one can appreciate some of the directions to be given for rodding a building he must have at least a limited knowledge of electricity and its laws, and this we shall now proceed to acquire, leaving directions for rodding to come later on page 24.

DISCOVERY OF ELECTRICITY.

If a small piece of cheap scribbling paper, after being warmed to dry it, be rubbed briskly upon the coat sleeve for a few moments and then placed against the window pane, it adheres to the glass, or it will adhere to the hand. (Fig. 1.) Another piece not rubbed, does not adhere to glass or hand. Hence the rubbing has produced some new property in the paper. The first experiment of this kind was performed by Thales, an ancient Greek, in the year 640 B.C. While walking along the seashore he picked up a piece of amber. In order to burnish it he rubbed it briskly upon his garments, and in some way or other discovered that after the rubbing the amber had the property of attracting light substances, such as dry leaves, twigs and chaff to itself. The Greek word for *amber* is *electron,* and hence this new property first discovered in the amber has come to be known as *electricity.* The paper in being rubbed upon the coat sleeve is said to have become *electrified.* In the year 70 A.D. electricity is again mentioned in history, but no real progress was made until the year 1600 A.D. Then Dr. Gilbert, a famous English scientist, discovered that all substances when properly manipulated could be electrified by friction just as the amber was.

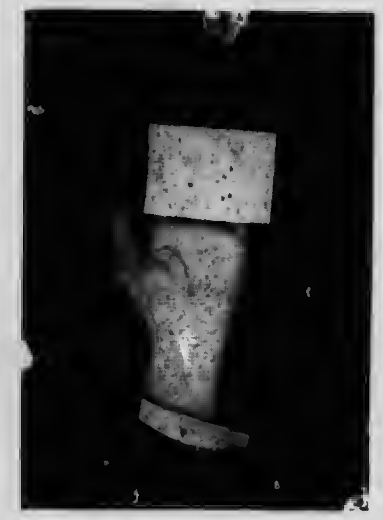

FIG. 1.—Paper rubbed briskly on coat sleeve adheres to hand. Paper is electrified by friction.

FIG. 2.—Pith balls suspended by *silk* thread to be used in experiments.

Here is another experiment. Several light pith balls, cut from the pith of an elder bush, are suspended from a little beam by silk threads. (Fig. 2.) They are free to swing about like the pendulum of a clock. Here also is a piece of cat's fur, while in this clamp is an ebonite or hard rubber rod. (Fig. 3.) A hard rubber comb would do just as well as the rod. To begin with, each one of these pith balls must be touched with the hand. The rod also must be touched from end to end with the hand. (Fig. 4.) If the rod be now placed near the pith balls we see that it neither attracts nor repels them. Both may be said to be "neutral." (Fig. 5.) But on rubbing the ebonite with the cat's fur and then holding it near a pith ball we see it is violently attracted to the rod. (Fig. 6.) It has been electrified by friction against the cat's fur.

Fig. 3.—Cat's fur (in hand) and ebonite rod (in clamp), to be used in experiments.

Fig. 4.—Before the experiments are begu the pith-balls and ebonite rod are bot touched by the hand to make them "neutral."

Fig. 5.—Pith-balls and ebonite neutral, no attraction between them.

Fig. 6.—Ebonite rubbed with cat's fur attracts pith-balls. Ebonite said to be electrified.

Placing the rod close enough that one of the pith balls can touch it, we see that immediately after contact, the ball, instead of being attracted, is strongly repelled. The ball has been electrified with part of the charge that was on the ebonite. Thus "like charges repel." (Fig. 7.)

Other substances will produce electricity. For instance, a silk cloth and a glass rod. If the glass be rubbed briskly with the silk and then placed near one of the neutral pith balls the ball is attracted. The glass rod has also been electrified by friction. If the glass is placed close enough that the pith ball touches it, then it immediately repels the ball. The ball on touching the glass becomes electrified by contact with part of the charge that is on the glass. Thus again, "like charges repel."

TWO KINDS OF ELECTRICITY—LIKE CHARGES REPEL; UNLIKE CHARGES ATTRACT.

But if the electrified glass be applied to the pith ball that was charged from the ebonite, the ball is attracted! Also charging the ebonite from the catskin, as before, and applying it to the ball charged from the glass this ball is likewise attracted. Thus, we see that the charge on the glass and ebonite are different. The glass will repel a ball charged from itself, but attract one charged from the ebonite; the ebonite, likewise, repels the ball charged from itself and attracts the one charged from the glass. (Fig. 8.)

Consequently, we see that there are two kinds of electricity, one of which is produced on ebonite by rubbing it with cat's fur and the other on glass by rubbing it with silk; and, furthermore, we are able to say that "like charges repel and unlike charges attract." This is a fundamental law in electricity. The charge found on the glass is called *positive* and that on the ebonite *negative*. It can also be shown that whenever a positive charge is generated in one body by friction an equal negative is generated in the other body which produced the friction.. Scientifically there is no inherent reason why these terms should not have been reversed when the distinction was first made.

CONDUCTORS AND NON-CONDUCTORS.

One of these pith balls is suspended by a *cotton* thread. If the electrified ebonite or the electrified glass be applied to this ball we see that it is very strongly attracted, and, further, that when it is allowed to touch the rod it clings instead of being repelled as were the others after contact. (Fig. 9.) In this position it remains until by and by it lets go and hangs straight down. (See figure 5.) Testing this ball now we see that it is not charged as the ones suspended by the silk threads were after contact and no charge is left on the ebonite! Both ball and ebonite are neutral! Consequently, we conclude that cotton and silk behave differently with regard to electricity. The cotton thread has allowed the charge to flow along it to the beam and away to the floor and thence to the earth. The cotton is called a "conductor," while the silk is called a "non-conductor." Copper, or indeed any metal, would conduct a charge away much faster than even the cotton. The words "conductor" and "non-conductor" are not absolute, but rather relative. There is probably no substance which is an absolute non-conductor of electricity. The term simply means that the substance referred to is a poor conductor.

THREE WAYS TO CHARGE A BODY, VIZ., FRICTION, CONTACT, INDUCTION.

We have seen two ways of charging a body with electricity. One is by "friction" and the other by "contact" with a charged body. There is a third, namely, by "induction." A brass body is supported on a glass base. Glass is a non-conductor, or insulator. The brass body is touched by the hand to make it neutral. If applied to a neutral pith ball there is no attraction. If neutral ebonite be placed

Fig. 7—A pith-ball suspended by *silk*, after touching the electrified ebonite is repelled. Part of the electric charge on the rod has passed to the ball, hence "like charges repel."

Fig. 8.—Negative ebonite rod between two balls, left charged negatively from ebonite rubbed with cat's fur, the other charged positively from glass rubbed with silk. Like charges repel, unlike charges attract.

Fig. 9.—A pith-ball suspended by *cotton* thread clings to the charged ebonite for a time. When the pith-ball lets go both are neutral, as in figure 5.

Fig. 10.—Brass conductor on glass stand, also pith-balls. Both neutral. No attraction.

Fig. 11.—Charged ebonite rod held *near* end of brass conductor. Pith-ball is attracted, hence conductor has been charged by the influence of a charge at a distance, i.e., by "induction."

Fig. 12.—Two brass plates on glass stands. Plates separated. One plate charged, as shown by the repulsion of the pith-ball.

near the brass there is likewise no attraction (Fig. 10), but when the ebonite rod is charged and held near, but not touching the brass body, we find that the pith ball is attracted! (Fig. 11.)

Thus we see the brass body has been charged not by either friction or contact, but by the influence of the charge on the ebonite rod a little distance away. The brass is said to have been charged by "induction."

A CONDENSER INCREASES THE CHARGE.

Two brass plates on glass stands are so arranged that they can be placed face to face. Each plate has a small pith ball attached by a cotton thread, which will show when the plate is charged. From the ebonite one of these plates is now charged by touching it a number of times with the rod which is each time rubbed with the catskin. The pith ball is strongly repelled, and stands out from the plate almost in a horizontal position. (Fig. 12.)

FIG. 13.—The same plate as in figure 12 (with the same charge) after plates were placed close together, but not touching. Note that the pith-ball has dropped showing less repulsion. More electricity can now be given to the charged plate. That is why the plates when close together are called a "condenser."

FIG. 14.—The same condenser as in Figure 13. Note pith-ball horizontal again as in Figure 12. As much extra charge was added to the left-hand plate as the plate originally held. The right hand plate has become charged by "induction," as shown by repulsion of pith-ball.

Now when the other plate is brought close to the charged one we note that the pith ball drops considerably (Fig. 13), and more electricity can be put on the charged plate, in the same manner as before, until the ball again stands in a horizontal position. (Fig. 14.)

Two insulated plates, side by side, are, consequently, called a "condenser." A condenser enables us to store up a much larger charge of electricity than either plate alone will hold.

CHARGES RESIDE ON THE SURFACE.

One other law should be mentioned, viz.: When a conductor is electrified the charge resides entirely on the surface. This can be readily proven, but the experiment does not lend itself to illustration by photograph.

ELECTRICAL MACHINE PRODUCES HEAVY CHARGES.

Thus far we have produced only very small charges, and at the expenditure of considerable labour in producing the friction. However, forty years after Dr. Gilbert's discovery, an electrical machine was invented by which large charges could be generated. At first condensers were not used on the electrical machines, but shortly afterwards they were applied in the form of Leyden jars. A Leyden jar is an ordinary glass vessel like a fruit jar, covered with tinfoil on the outside, about half way up, and on the inside about half way up. These two tin foils form the two plates of the condenser, and by means of Leyden jars very strong charges can be stored up.

Figure 15 shows an electrical machine consisting of two glass plates, one of which is rotating and the other stationary. Without the Leyden jars it produces a very fine spark which will jump about two inches of space. When the two Leyden jars are connected up the spark is very much stronger, and sufficient to give one a severe shock. It will jump five or six inches of space, and the spark looks exactly like a flash of lightning.

Fig. 15.—An electrical machine. It is being turned by crank in rear. Note spark between knobs.

Fig. 16.—Electrical machine with points attached to positive and negative poles. No flash can be produced.

ELECTRICITY LEAKS OFF POINTS.

With this machine one can demonstrate another fundamental principle. If two sharp wires are attached, one to the positive side of the machine and the other to the negative, and the points turned towards each other we find that the machine does not produce a spark and cannot be made to produce one, if the electrification takes place gradually. (Fig. 16.) If a lighted candle is held to one of the points it is extinguished when the machine is turned. There is sufficient wind at this point to blow out the candle. (Figs. 17 and 18.)

There is only one conclusion possible, viz., that the electricity formed by the machine leaks off these sharp points, preventing sparks from occurring.

FRANKLIN PROVES THAT LIGHTNING IS ELECTRICITY.

The electrical machine was discovered in 1640, but it took one hundred **years** to perfect it and produce the large sparks, and to learn the fundamental principles of electricity. In 1751 Benjamin Franklin, observing the similarity between the lightning flash and the sparks that could be produced by an electrical machine, came to the conclusion that lightning was nothing else than a discharge of electricity, or rather the light produced by such discharge. To prove this, he sent a kite up into the clouds as a thunderstorm was approaching. The string which held the kite was connected with an electric key in the laboratory. As soon as the string became wet electric sparks occurred at the key, which were in every respect like those produced with the electrical machine. Franklin's reasoning then ran something as follows: If lightning is produced by a discharge of electricity, then it must obey the laws of electricity. Hence, it should be possible to prevent lightning in many cases, just as an electric spark can be prevented in this machine by having a pointed wire attached to each side, or if a flash does occur, it should be possible to conduct the current to the earth by wire without injury to the building bea[illegible] the wire. In other words: If lightning is produced by a discharge of electric[illegible] lightning rods must be a practical possibility.

Fig. 17.—Candle-flame held between points of electrical machine. When the machine is not turned, i.e., when there is no charge, the flame burns straight up and sharp in outline.

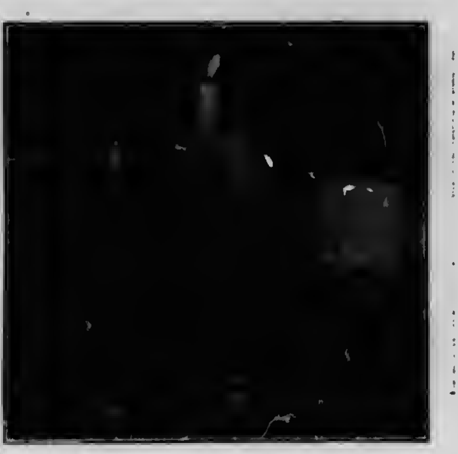

Fig. 18.—But when the machine is turned the candle-flame is blown sidewise. If the candle is held up level with the point the flame is blown out. The wind shows that electricity is leaking off the point.

After Franklin's results were published lightning rods began to be installed on farm buildings through the United States, and later in Canada, but in the early stages lightning rod companies knew very little of the laws of electricity, consequently were unable to instruct their men as to how buildings should be rodded, and, hence, in some cases, the rods did not produce the protection they were expected to. Besides, numerous swindles in connection with lightning rods were worked off on the farmers, so that in time lightning rods came into great disrepute. However, Sir Wm. Snow Harris, in England, devised a system of lightning protectors for ships, which completely did away with the one-time tremendous loss caused by lightning to the ships of the British Navy. So effective was his system that the late Queen Victoria bestowed a knighthood and an annuity upon him in recognition of his great service to the navy, and thereby to the British Empire. Throughout England, Germany and France lightning rods became the subject of study, and many buildings, especially costly ones like the great churches and cathedrals, were protected by lightning rods, so that the loss to buildings of this kind by lightning was almost completely overcome. This extensive use of the lightning rod in Europe, together with continued study in America, has had the effect here of drawing attention again to the subject.

In America the one man who has done more than perhaps any other to bring lightning rods again into favour is Mr. West Dodd, of Des Moines, Iowa. A man of great energy and scientific insight, he took up the lightning rod question twenty-five years or more ago, when rods were in disrepute, and pursued it with such tenacity and skill that he has overcome a hostile public sentiment and convinced the people of the Middle Western States that lightning rods are an unqualified success. His own State of Iowa reports 50 per cent. of its farm buildings rodded, perhaps the highest percentage of any similar area in the world. Motoring through that state for a distance of fifty or sixty miles, the writer verified this percentage by actual count. In his work Mr. Dodd adapted the electrical machine to demonstrate the thunderstorm and the lightning stroke, and then used toy barns, houses, animals and rods to demonstrate the phenomena of lightning and the efficacy of lightning rods. With this equipment he appeared before the insurance companies of Iowa and other states from time to time, and demonstrated scientifically that rods must be effective. His teaching bore fruit in numerous companies granting reduced rates on properly rodded buildings.

Fig. 19.—The electrical machine as modified by Mr. West Dodd for demonstrating the thunderstorm. Note earth plate E. and cloud plate C.

Fig. 20.—A toy house with metal chimney, screen door, eave-trough and balcony is set on earth plate and machine turned. Note flash to chimney and sparks down screen door—the door is constructed with air-gaps, in jumping which the current causes sparks. Dangerous to stand by screen door during thunderstorm.

THE ELECTRICAL MACHINE MODIFIED TO REPRESENT A THUNDERSTORM.

Mr. Dodd attached a metallic plate to the negative side of the machine; to the positive side another plate which hangs a few inches above the first one. The lower plate represents the earth, and the upper one the cloud. (Fig. 19.)

When the machine is turned the "cloud" gradually becomes charged with positive and the "earth" with negative electricity, and by bringing the cloud and earth close enough together sparks, or flashes, occur which look exactly like the flashes of lightning seen during thunderstorms. After each flash the plates again become charged *gradually*.

RODS ON TOY BUILDINGS PREVENT FLASHES.

Here is a T-shaped house with metal gutter to the eave-trough, whence two conductor-pipes run down nearly to the ground. One conductor-pipe is connected with the metal floor of the balcony. The house, which has a screen door, is placed on the earth plate. (Fig. 20.) As the machine is turned a flash occurs to the chimney, and thence the current follows the gutter and eave-trough, then flashes to the screen door, which is so constructed that the current has air-gaps to jump, making tiny sparks as it does so. From the door it flashes to the ground plate. Note that flashes or sparks occur only where the current jumps air-gaps.

FIG. 21.—A woman stands under the balcony and is struck. Note short flash from balcony to woman's head. The gutter, conductor-pipe, metal floor of balcony and the woman form an easier path than that by the screen door.

FIG. 22.—The woman goes to the rain barrel for a pail of "soft water" and is struck. This path is now the easiest for the flash.

A little metallic figure, representing a woman, is placed in front of the screen door, and the flash strikes the woman instead of jumping the air-gap at the floor. If the woman stands under the balcony the lightning takes a new path. (Fig. 21.) Instead of going by the screen door it follows the eave-trough to the balcony floor, thence strikes the woman and passes to the earth. The new path offers less resistance than the old.

If the woman goes to the rain barrel for a pail of "soft water" the lightning takes another path still, following down the gutter, eave-trough, and conductor-pipe, and thence striking the woman. (Fig. 22.)

A copper wire without points is now put on the building, so it is in contact with the chimney and leads down to the earth plate at each end. The flash now follows the wire, and the woman is perfectly safe, standing at the eave-trough, under the balcony, or at the screen door. (Figs 23A and 23B.) The copper wire offers less resistance than any of the other paths, and naturally the flash follows the path of least resistance.

But if this wire is removed and another put on with two sharp points sticking upward towards the cloud, the flash is entirely prevented. (Fig. 24.)

If the lighted candle be applied to these points it is blown out as before, consequently, the electricity generated by the machine is leaking off these points and gradually neutralizing the opposite charge in the space between the cloud and the earth.

FIG. 23.—A wire is put along the ridge, touching the chimney and going down to the ground plate at each end of the house. The flash now goes down this wire, and the woman is safe at rain barrel, under balcony or at screen door.

FIG. 24.—If, however, wire has uprights and points no flash can be produced, which is better still.

FIG. 25.—Barn with hayfork track, fired by flash. If track had been grounded current would have followed ground wire, and no fire would have occurred. If points had been used flash would have been prevented.

Here is a barn with cupola and hay-fork track. The flash enters the cupola, jumps to the track, and thence down at one end of the barn. If a little gasoline is put in the door at the end of the barn it is at once fired, just as hay would be. (Fig. 25.) As in previous cases, the wire without points will carry the stroke off without setting fire *if connected with hay-fork track,* while the one with points will prevent the flash entirely.

METALLIC ROOFS.

It is sometimes said that a metallic roof is perfect protection from lightning. If such a roof is put on one of these buildings, it is struck just the same as if it were an ordinary roof. (Fig. 26.) Note flash at stove (which is constructed with air-gaps to cause sparks). It is dangerous to stand by the stove during a thunderstorm.

If, however, a corner of this roof is connected to the ground by a wire, the current follows the wire. (Fig. 27.) No sparks at the stove now.

But a flash can be prevented from striking that metallic roof, as in the other cases, in two ways: First, by using lightning rod points; secondly by putting a sharp edged or notched ridge-board on the top. (Fig. 28.) We might here refer to the practice of using a round metal form on the ridge of a metal roof. Nothing could be more dangerous than this so far as lightning is concerned unless points of some kind are provided. The round form prevents the electricity from leaking off, and consequently tends to store up a charge and cause a stroke. If instead of the round a sharp-edged form or one with teeth were used, it would be almost impossible for a metallic-roofed building to be struck by lightning, if two, or better, four, corners were connected with the earth by ground wires.

FIG. 26.—Metallic roof struck by lightning. Note flash down front of stove. The stove is constructed with air-gaps in jumping which current makes sparks. Dangerous to stand by stove during thunderstorm, if house is not rodded.

FIG. 27.—Metallic roof with one corner grounded. Flash still occurs, but goes down ground wire—no sparks at stove now.

WIRE FENCES.

Here is a wire fence, which is attached to the earth-plate. As the machine is turned a flash of lightning jumps from the cloud to the wire and from the wire to the earth. (Fig. 29.)

If a horse is stood beside the fence, instead of the lightning jumping the air-g from the wire to the ground it strikes the horse. (Fig. 30.)

If, however, the fence-wire is connected with the ground by means of a ground-wire the horse is perfectly safe. (Fig. 31.)

Moreover, if the ground-wire be let project above the fence, ending in a sharp point, no flash will occur. (Fig. 32.) The charge is neutralized by leaking off the point.

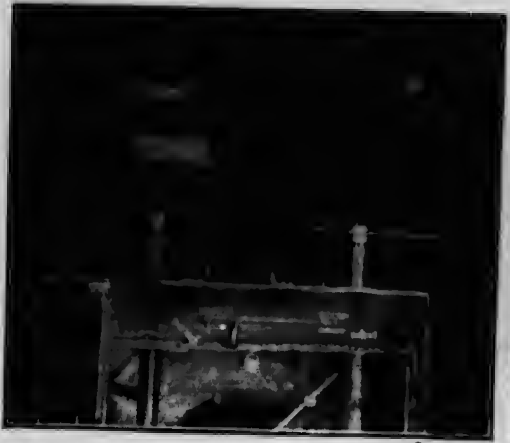

Fig. 28.—Metallic roof grounded, and with notched metallic ridge. No stroke can be produced. Ordinary lightning rod points would be as effective, and probably more durable.

Fig. 29.—Lightning strikes a fence and jumps air-gap to earth.

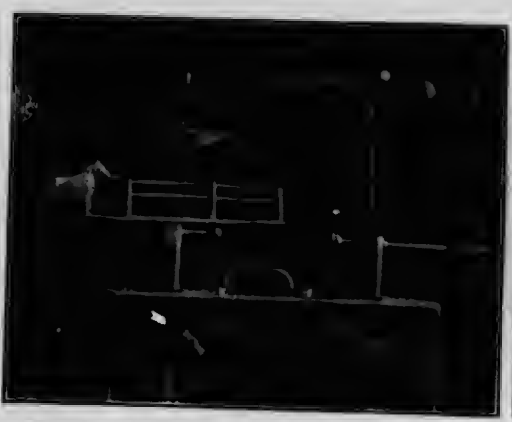

Fig. 30.—A horse standing by the fence, however, forms an easier path, and the horse is struck. Note flash from fence to horse's nose.

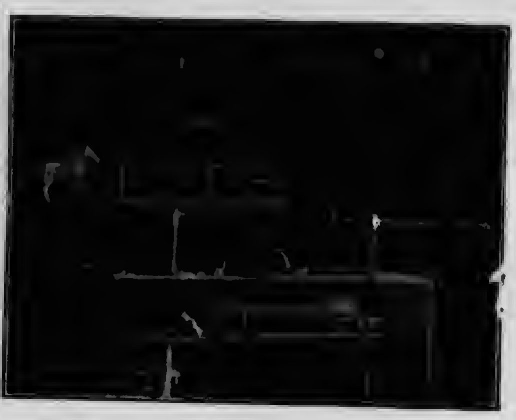

Fig. 31.—If, however, the fence wires are grounded, the flash follows the ground wire and the horse is safe.

Consequently, wire fences should be grounded, and the ground-wire projected above the fence if the stock is to be protected in the best possible way.

It is hard to conceive how any person could follow these experiments and phenomena and doubt the value of lightning rods. We have seen that by means of rods on these little toys we can either carry off a stroke without damage or we can prevent a stroke altogether. Hence, if in rodding our buildings we observe the laws as have been observed in these experiments the buildings must be largely protected.

But, you say, in a real thunderstorm the clouds and earth are much larger, compared with the real buildings, than the cloud and earth in this experiment, and the electric charge is infinitely greater than that produced by this small machine. Quite so, but the real cloud and earth are 20,000 times as far apart as the cloud and earth of this machine, and this great distance requires the entire lightning charge to break through the atmosphere. Hence, anything that would relieve the electric pressure just a little bit would prevent a flash. Lightning rods *must* relieve the pressure if lightning is produced by electricity. Consequently, we expect that real lightning rods in a real storm would protect the buildings just as well as these little ones do in these experiments.

Why Strokes Sometimes Occur in Spite of Rods.

But, one is disposed to ask, if rods in many cases prevent strokes, why not in all? In the foregoing experiments the cloud and earth have in all cases been charged *gradually*, and when so charged flashes between them can be prevented. However, the machine can be modified to unload its entire positive and negative charges to the cloud- and earth-plates in possibly one-thousandth or one-millionth part of a second. When this occurs the points cannot let the charge leak off fast enough and consequently a flash follows. This shows that it is *possible* for a rodded building in a real thunderstorm to be struck. Generally, real thunderclouds become charged gradually and lightning strokes can be prevented, but in rare cases a cloud receives an immense charge in a very small fraction of a second. This is sometimes brought about in the following way: Two clouds lie near each other. The buildings under the first are rodded, but not under the second. A flash occurs between the second and the ground, followed by a flash between the first cloud and the second. This impulsive rus[illegible] the pressure in the first cloud so suddenly t the leakage does not neutra[illegible] charge as fast as the difference in pressure creases, hence a flash occurs. But that flash is probably much weaker than if the ods had not been there, and in most cases of this kind the rods will conduct the current to the ground without damage.

Fig. 32.—But if the upper end of theground wire projects above the fence in a point, no flash occurs, which is even better.

THE CAUSE OF THUNDERSTORMS.

Atmospheric electricity has been the subject of considerable study. In earlier days friction of the air against the earth and objects on it, and also evaporation, have been mentioned as possible causes of atmospheric electrification, but during the last few years another explanation has been advanced. It has been proven that the earth is always negatively charged, and that the air is a conductor, although a poor one, to be sure. Since a charge cannot reside within a conductor it follows that the charge on the surface of the earth must be transferred more or less quickly to the outside of the conducting atmosphere. Within the last four or five years the rate at which the earth loses its charge to the air has been measured by Dr. G. C. Simpson, of Simla, India, and although the rate of loss is small per square foot or per square yard, yet when the entire surface of the globe is considered it amounts to a constant current of more than 1,000 amperes! Despite this continual loss, the earth's charge is maintained at a uniform potential, consequently it follows that the earth must be receiving an amount of negative electricity equal to that lost. The idea at once occurs that the rain brings back the required negative charge. However, careful measurements, at half-a-dozen different places distributed over three continents, show that in all kinds of rain more positive than negative electricity is brought to the earth! This leaves the source of renewal of the earth's charge still unknown, and, moreover, offers no explanation of the existence of positive charges in the air, so that the difficulty surrounding the problem of atmospheric electricity has been increased rather than diminished.

We do know, however, that under certain conditions, when water vapour high up in the atmosphere condenses into minute drops these become charged with electricity. When one of these drops is formed from several smaller ones there is less surface for the electricity to be spread over, and consequently it becomes more dense. Thus it happens, that in the cloud there are drops of various sizes, some of which are more strongly charged than others. The weak charges appear negative to the stronger, and consequently the electricity has the effect of attracting the drops together more rapidly than they otherwise would unite. This accounts for the very sudden development of thunderstorms. When the condensation has gone on sufficiently the cloud becomes one great conductor, and the electricity leaves the surface of the drops and collects on the outside of the cloud. This produces another increase in intensity of the charge. Then, again, the cloud acts as one plate of a condenser, the earth as the other, and with the air between they actually form a great condenser similar in principle to the little plate condenser shown in Figure 13. Thus it is that such immense charges of electricity are produced in the cloud. As the positive gathers together in the cloud, the negative in the earth collects directly beneath, and the attraction of these unlike charges draws the cloud downward, so that all things are favourable to a violent flash once the electric pressure or attraction between the cloud and earth is sufficiently high to make the electricity jump the decreasing space between them.

NATURE OF LIGHTNING DISCHARGE.

But the lightning discharge is not a single rush in one direction. A steel spring or a violin string drawn aside and let go will fly away past the centre, then back, and continue to oscillate a large number of times, the oscillations gradually dying out as the energy is dissipated. That is just what happens in the lightning stroke. When the current breaks through, the discharging process goes too far, the charges on the cloud and earth becoming reversed, and these in turn discharge, and this reversing and redischarging is repeated over and over again, probably a million times a second, until the energy of the stroke is exhausted. The stupendous frequency of the oscillations makes the current travel almost entirely in the surface layers of any conductor it may follow.

Let us now study the conditions on the earth during a flash. Look at the frontispiece, page 2. Immediately you say, "I never saw the flash spread out like that either on the earth or in the cloud." Quite so. But if we return to our electrical machine, and on the earth plate set a flat tin dish containing moist earth, then wet one of our toy barns, set it on the earth in the tray and turn the machine, we see at every spark innumerable ramifications of the flash spreading out over the earth! When the pressure breaks through between the cloud and wet barn, the charge from all parts of the earth-plate is in such a hurry to make its way up to meet that from the cloud that it doesn't take time to follow all the irregularities of the earth's surface, but jumps through the air from point to point, causing sparks everywhere it does so, and the current reverses a few hundred thousand times during one flash.

Thus we get the idea that when a stroke occurs the earth for hundreds of feet around the object struck is in a highly electrified state and the electrification changes from positive to negative many times during the flash. Hence there is an alternating current to and from the object struck. This takes the path of least obstruction, following conductors with least resistance and self-induction, and often flashing or sparking from one to others near at hand. That's probably what killed the cattle—the current jumped the space between them and the fence, and the shock killed them. The death of the pigs is not so easily explained, as apparently they were not close to any other conductor—and this is not an imaginary case. The cut is from a drawing of Mr. West Dodd's, based on an instance that came under his notice, where pigs were killed in an open yard, although the stroke occured to the barn some distance away.

In an actual flash of lightning we do not see its ramifications on the earth and cloud, but from our experiment with the toy barn and tray of earth we know beyond peradventure of a doubt that during the flash there are currents from all directions to the earth focus, and by analogy we know the same must be true in the cloud. Did not the flash so blind its observer for the instant, sparks between conductors on the earth should readily be detected. So the earth- and cloud-ramifications in the frontispiece represent not streaks of light but alternating currents of electricity and the lines of force which produce those currents.

WHY NEWLY FILLED BARNS SEEM MORE LIKELY TO BE STRUCK.

In this connection we should like to deal with a phase of the subject about which there seems to be more or less misconception, viz., the claim that barns newly filled with hay or grain are more frequently struck and burned than any other class or condition of building. Whether such barns are more often struck remains to be proven, but there is perhaps little doubt that if struck they are more frequently burned than if empty. Most of us have no doubt heard the old explanation which runs something as follows: After the grain is stored in the barn it "sweats" and gives off vapour to the air, and this moisture ascending in a column above the barn forms the easiest path for the lightning flash, for moist air is a better conductor of electricity than dry air. Some vary it by saying "gases" are given off, which being interpreted must mean either vapour or carbon dioxide, for chemists state that there is no chemical action and chemically no gases are given off; while bacteriologists say that some carbon dioxide may be given off in case the hay or grain heat somewhat, which they do unless comparatively dry, but no other gas could be. Now carbon dioxide being heavier than air at the same temperature could not rise more than a few inches above the mow—just enough to allow it to become cool. Hence the explanation depends upon the water vapour. What has always puzzled us is to know how the vapour could escape from the barn fast enough to form a column, even in calm weather, much less if some wind is blowing. Besides, when a thunderstorm is approaching the atmosphere is usually so humid as to be oppressive, and air escaping from the barn would probably be drier than that outside. This would be particularly true when the rain begins to fall, for then the outside air is saturated, and hence any that might escape from the barn would tend to make that above drier than elsewhere. In view of these considerations we cannot see any possibility of the vapour in the barn or from the barn having any effect whatever in causing lightning strokes. But we have always hesitated to attack the theory because we had nothing to offer in its stead, except that hay and grain with their light leaves and chaff are easily ignited, and as they touch the barn in thousands of places, even a small spark anywhere in the building is almost sure to fire it. This, however, would not account for strokes on these barns being more frequent than on empty ones, if such be the case.

Perhaps the greater inflammability due to the presence of the hay and grain is sufficient explanation. We have seen on page 23, that when a lightning discharge occurs there are surgings of electricity on the conductors in that vicinity, which doubtless produce many tiny sparks, any of which occurring in the barn would ignite the dry leaves of the plants. Sometimes in cases of this kind it is said " the barn just seemed to take fire all over "—doubtless a case of many sparks each setting its own little fire. There may sometimes be another cause aggravating the danger, viz., that owing to the heating process in the mow the grain may be nearly hot enough to take fire itself, in which condition it is more easily ignited by a spark.

How to Rod a Building.

Let us now enquire: " When is a building properly rodded?" The first problem is, what kind of rod shall we use?

1. *Kind of Rod.*—Until recently iron and copper were the only two metals thought of in connection with lightning rods. Now aluminum also becomes a competitor, as there are rods of this material on the market. For a long time copper was considered the only metal for this purpose, the reason being that it conducts a steady current of electricity more than six times as well as iron, the size of wire being the same in both cases. But this difference may be overcome by using iron wire six times as large in cross-section as the copper. This, however, makes too heavy a cable. But the conductivity of steel is only about seventy per cent as great as that of iron, so that steel rods would have to be considerably heavier than iron to have the same conducting value. As standard copper rods weigh at least three ounces to the foot, the iron cable would have to weigh more than one pound and steel rods almost a pound and three-quarters to the foot to be as good conductors of steady current as the copper rods in general use. Hence it is not practicable to make iron or steel rods that will be as good conductors of steady current as the copper rods.

SELF-INDUCTION.

There is another phase of this problem, however. Between the years 1888 and 1892 Sir Oliver Lodge carried on an investigation of the phenomena of lightning, by means of laboratory experiments, and to his surprise, as well as that of many scientists and of the whole lightning rod fraternity, he found that an iron wire will carry off a sudden rush of electricity better than a copper wire of the same size! Every sudden discharge or current of electricity induces an opposite current along the same path. This is known as "self-induction." When the current ceases, self-induction again takes place, this time opposing the drop in current just as it formerly opposed the rise. Thus with an alternating circuit the self-induction is high, and increases with the frequency, becoming enormous in the lightning discharge, which oscillates about a million times per second. When a flash occurs the resistance of the rod may frequently be insignificant compared with that offered by self-induction. A steady current has no self-induction. While iron has greater resistance to the steady current than copper, yet the self-induction of the iron is less than that of copper in case of an electric spark or a flash of lightning. Basing his judgment on this and related facts, Lodge stated that, in his opinion, the day of copper lightning rods was done, although he added as a rider that in cities and towns where coal is burned he thought the iron rods would not prove durable, owing to the action of the fumes upon the zinc coating of the galvanized wire. We are inclined to think that even in the country the question of durability is an important one. Galvanizing is sometimes poorly done, and even if well done corrosion takes place wherever the rods are cut or scratched. The same does not apply to a copper wire.

But it seems to us that in this judgment Lodge paid attention almost entirely to one duty of the lightning rod, namely, to carry off the flash in case the building is struck, for in one place he says: "I have at present no great faith in the effective discharging power of a few points." By the data given at the commencement of this bulletin we have seen that lightning rods have another and a greater duty to perform, namely, the preventing of strokes from occurring. To prevent a stroke there must be a gradual flow of electricity along the rod to the point and into the air, or *vice versa*. As a matter of fact, it is easy to demonstrate that there is a steady flow along the wire when the points on the toy buildings prevent sparks. The same must be true in the real thunderstorm. Now, for steady current, copper rods have a higher conducting power than iron ones, hence, for preventing strokes copper rods are the better, while for carrying off strokes iron ones are the better. But copper rods are made heavy enough to carry the "impulsive rush" and iron ones conductive enough to carry the steady current, hence, durability is the criterion, and in this copper is indisputably superior to iron.

In Michigan the Protected Mutual will not accept a risk on a building equipped with iron rods. and the weight of copper rod on all of their buildings is at least 2½ ounces per foot. The efficiency of their rods, as already mentioned, is 99.9 per cent. The Patrons' Mutual, however, insures in its rodded class, whether the rods are of iron or copper—and many of their buildings are rodded with iron, and yet in eleven years they have had to pay only three lightning claims on rodded buildings, indicating about the same efficiency as with the Protected Company. So experience would seem to support what has already been said, viz., that rods of any metal will give good protection as long as they are in good repair and properly installed. So that the relative value of the rods depends upon their respective durability.

COMBINATION RODS.

There are rods on the market made of a sheath of copper surrounding iron or steel centre. All these are even less durable than if made of iron alone, because of electrolytic action between the two metals and rapid rusting either with or without this action. Different farmers who have had rods of this style on their buildings and have examined the groundings from time to time have told us that in their experience with rods having copper sheath and strip of iron or steel in the centre, sometimes with two steel wires added for strength, the life of the iron has proved to be from ten to twelve years. On the 3rd of February, 1914, the writer personally inspected one of these rods that had been on a building eight years and found that in the portion of the cable running along the ridge of the barn the iron strip and the steel wires were almost completely destroyed by rust, in spite of the fact that both strip and wires had once been galvanized! Fig. 34 shows the result better than words.

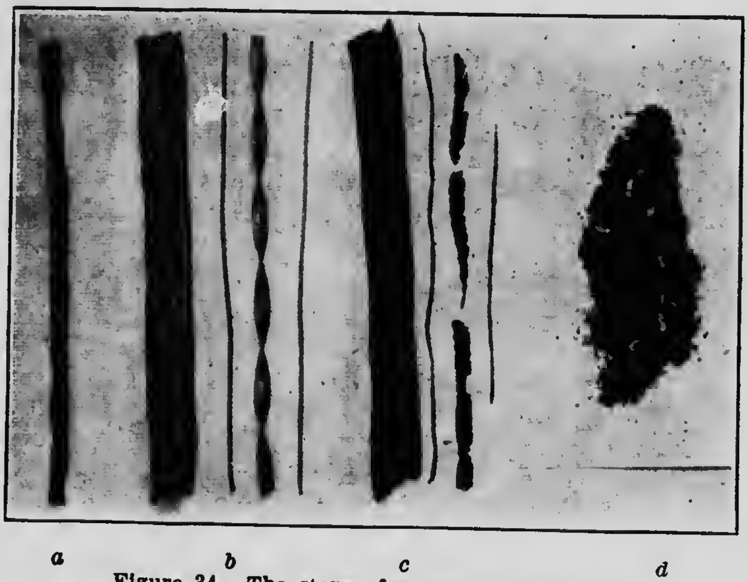

Figure 34.—The story of a copper-covered rod.

a. The new rod complete.
b. The new rod torn to pieces. Note the copper sheath, two No. 10 galvanized steel (iron) wires, and ½-inch strip of No. 20 galvanized iron.
c. All that was left of a rod that had been in use eight years. The sheath in good condition, but the steel wires and strip nearly all rusted away.
d. The rust taken from the sample one foot long shown in *c*.

The portions of the rods running up the gable ends were in fair state of preservation. The ground-rods were frozen in so that their condition could not be determined. One could hardly have anticipated such destruction up on the ridge of the barn, but the explanation is easy. During rains the water entered the sheath, wetting the iron, and after the storms the rods became heated, and moisture and warmth combined produce most rapid rusting, a phenomenon with which all are familiar. In much less than eight years the iron in those rods ceased to have any value, so far as that portion along the ridge was concerned. And it would seem impossible that the iron in the ground-connections, subject to perpetual moisture, could have escaped the effects of rust.

In the country great quantities of this type of rod have been used. What percentage of it has become defective we have no means of knowing. **Of course,** so long as the copper sheath remains intact there is protection, because the chief function of the iron is to add strength to the rod, its conducting power being but small as compared with that of the sheath.

ALUMINUM.

Aluminum is about half as good a conductor as copper, the size of wire being the same in the two cases. But if aluminum wire is twice as large in cross-section as the copper, then their conducting power is equal. Aluminum, so far as we can see, should prove just as durable as copper, although we must remember that it is a peculiar metal, and experience may bring out some practical weaknesses that as yet may not have developed.

So many questions are asked regarding the resistance of iron, copper and aluminum that it is thought wise to give a few comparisons. Figure 35 shows samples of six copper rods on the market in Ontario. In Figure 36 the two long samples, Nos. 7 and 8, are of iron, and the short ones, Nos. 9 and 10, of aluminum. These ten rods are compared in table below:

COMPARISON OF SOME CABLES.

Rod No.	Construction.	Weight per Foot	Diameter of cable.	Actual area of cross-section of metal.	Resistance per 1000 feet.	Heat that one foot of the rod will stand before melting.	
		Ounces	Inches.	Sq. Inch.	Ohms.	Calories.	Melting Point.
Copper 1	Sheath of No. 30 copper, 2¼" wide, wrapped and twisted and locked around strip of No. 21 copper, .45" wide, and two No. 10 copper wires	3.263	.55	.0566	.1348	9397	2012° F
2	28 No. 17 copper wires and a strip of No. 20 copper, ⅛" wide.	3.250					
3	29 No. 17 copper wires.	2.65°	.40	.0460	.1659	7631	
4	Same as No. 1, but sheath not locked, strip being No. 22 and .50" wide	3.28°					
5	31 No. 17 copper wires, woven in a flat ribbon	3.065		.0491	.1552	8152	
6	7 No. 9 copper wires ..	4.637	.35	.0714	.1071	12,880	
	1 No. 2 copper wire ...	2.869	.258				
	⅝" copper tube, No. 22 gauge, used as uprights	2.500	.625	.0471	.1620	7199	
Iron 7	12 No. 9 steel wires (home-made)	5.800	.45	.1225	.4954	24,389	2840° F
8	5 No. 7 and 1 No. 9 steel wires	4.620	.35	.0916	.6624	18,985	
Alumin'm 9	19 No. 8 aluminum wires	4.504	.65	.2445	.0542	16,818	1157° F
10	7 No. 6 aluminum wires.	2.037	.50	.1443	.0952	7606	

Rod No. 5, the woven ribbon, is just on the 3-ounce limit for copper, and we may take its resistance and heat capacity as the standard requirements in these two respects. No. 3 is too light. Nos. 2 and 4 are almost identical with No. 1 in resistance and heat capacity because almost identical in weight. No. 6 has about 1½ times the standard amount of copper and is unquestionably the best of the six copper rods. Its resistance is lowest, meaning it is the best conductor. Its heat capacity is highest, its durability greatest. However, judging by data at hand it is probably a needless expense to use such a heavy cable.

The two steel (iron) rods are both much heavier than the standard copper, but their resistances are 3 1-3 and 4 1-3 times as great, showing that they are only about 1-3 and 1-4 as good conductors respectively of steady current as the standard. In heat capacity they, of course, head the list.

The aluminum rods have the lowest resistance, that is, they are the best conductors of steady current. The large aluminum has about twice the heat capacity of the standard copper, so that this cable, like No. 6, seems needlessly large. No. 10, however, is just a shade small, being rather low in heat capacity. So far as we are aware, no specifications have heretofore been laid down as to the minimum weight for aluminum rods. To have the same heat capacity as the standard copper would require 2 1-7 ounces per foot, but in view of the fact that the melting point of aluminum is only 1,157 degrees F., while that of copper is 2,012 degrees F., it would seem prudent to require a little greater heat capacity than in the copper. Consequently I should be inclined to specify at least 2 1-4 ounces per foot for aluminum rods. Extensive use will be necessary to determine practically whether this will be ample, though so far as we can see it should be.

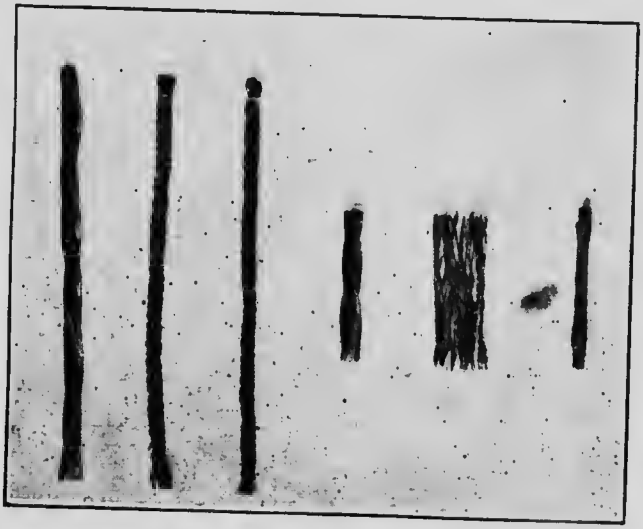

FIG. 35.—Six different makes of copper rod. For properties see Table

Iron has a melting-point of 2840°F, the highest of the three. That's one reason why the iron has such high heat capacity. The other reason is the weight of the rod. The aluminum has the lowest melting point of all. Whether this will be any practical detriment to rods of this metal also remains to be established by extended use.

In this comparison no attention has been paid to "surface," although much stress has from time to time been laid upon this by makers of various types of rods. Sir Oliver Lodge's experiments, which show that a thin broad strip has less self-induction than a wire of the same material and weight have been taken as an indication that we should have great surface of conductor, and durability and convenience of installation have sometimes been sacrificed to surface. We should not forget that when it came to the practical side of the question Lodge recommended the more rugged types of conductor, such as solid rod or strong cable, in explanation whereof he said: "It is because I doubt whether decently substantial conductors are in any real danger from heat that I have asserted the advantage of greater surface to be but small." Consequently shape of rod is immaterial, so far as efficiency is concerned, and a tape or other form designed for great surface has by reason thereof no practical pre-eminence over other shapes of rod.

SIDE FLASHES.

Sometimes part of a lightning-charge will side-flash from the rod, jumping several feet of air gap in doing so. Why? The total obstruction to the current is made up of two parts, the resistance of the wire, and the self-induction. The more suddenly the current comes on and the higher the frequency of alternation the greater the self-induction, and this is the larger factor when a stroke occurs. The self-induction of a short air circuit is sometimes less than that of a long metallic circuit, hence the side-flash in such cases.

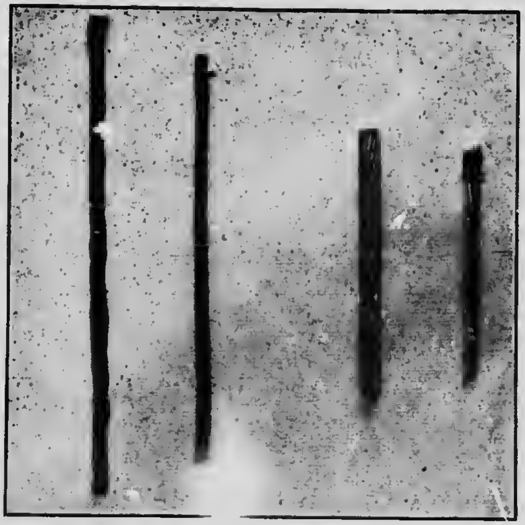

FIG. 36.—Two iron rods (long) and two aluminum rods (short).

GROUNDINGS.

Ground Connections.—For an ordinary building, not an L or T, at least two groundings should be made, preferably at corners diagonally opposite, though this may be modified to meet conditions, e.g., to run near conductor pipe from eave-trough and which should be connected to the cable as indicated later. Another factor that may sometimes influence the selection of the ground-rod locations is the presence of manure and the liquid from it. The ammonia in the manure will attack the copper rods, and in a few years eat them off. The heat of the decaying manure will hasten rusting of the iron rods. Consequently ground-rods should be located where there is no manure.

Some rodding companies in Michigan use a length of half-inch gas piping to protect their ground-rods. This pipe is first closed at one end by welding and then sharpened, after which it is driven in the earth point downward until the top is within a foot or so of the earth's surface. The cable is then shoved down inside the gas pipe till it reaches the bottom, and the pipe then flattened at the top till it presses firmly on the cable. The Patrons' Mutual of that State prefers that the groundings be thus protected before they accept the risk in their rodded class, and as already stated they have paid in eleven years only three lightning claims on rodded buildings. The Protected Mutual, on the other hand, will not accept a risk at all if they discover that the gas-pipe protection is used. They make two objections against it, one that the pipe acts somewhat as a choke-coil, the other

FIG. 37.—The drill (in left hand) used in making groundings.

that the cable is frequently eaten off at the top of the pipe by the electric current passing from the cable to the pipe, thereby putting the system out of order. Occasionally, however, their inspector overlooks a gas-pipe grounding and accepts a risk on a building so rodded. Since the 1912 report of the Protected Mutual they have lost their first rodded building by lightning, and curiously enough it was one with the gas-pipe groundings. On examination it was found that the cable was nearly disconnected, only two or three of the fine copper wires remaining intact. Whether the injury was done in closing the gas-pipe too tightly on the cable or by the current eating the wires off was not determined. It would seem that as yet this method of making groundings is open to some question and it would appear wiser to locate the ground-rods where there is no manure, then there is no need for the gas-pipe.

A simple way to make a ground-connection is illustrated in figures 37, 38 and 39. In figure 37 note the drill 10 feet long. It is a piece of half-inch iron rod, with point swedged to make it about five-eights or three-quarters of an inch in diameter. An eye for a hand-hold is formed on the upper end of drill. A hole large enough for a pail of water is dug in the ground. The hole is filled with water, and the drill is placed in the centre of the hole and gradually worked downward. More water may be poured in if required. When the drill is down full depth (see Figure 38) it is withdrawn and the cable carefully slipped down into the hole (see Figure 39). The grounding shown in these figures was made while rodding a silo, and took probably twenty minutes after the hole was dug.

FIG. 38.—Drill down 10 feet.

FIG. 39.—Ground rod down 10 feet.

It is sometimes advised to dig a large, deep hole and bury a ground-plate to which the ground-rods are attached. This does not appear to be necessary in general farm conditions. In Michigan where the efficiency is 99.9 per cent. the ground-connections are made in a manner similar to that just described and shown in the photographs. If efficiency without ground-plates is 99.9 per cent. there seems to be no urgent need for them. Where the rock is near the surface and the soil becomes dry to the bottom during the summer a ground-plate would be of some value, especially if imbedded in coke, for coke, besides being a conductor, holds moisture well, but better results would probably be secured by sinking the ground-rod into a well or a good crevice in the rock, or a stream of water if one should be near. Sometimes in shallow soil a large flat stone is laid over the ground-rod "to hold the moisture." There is doubtless some virtue in this, though the ground-plate and other methods are better.

On an L- or T-shaped building there should be at least three groundings. Two of the damages suffered by the Protected Mutual happened in the following manner: Both buildings were T-shaped. There was a ground-rod at each end of the main part, and from the main system a cable ran along the ridge of the other wing and a point was placed about five feet from the end, but the cable was not continued further, there was no ground-rod for this part of the system. Later a telephone line was run into the house, entering near this stub end. The lightning flash struck the point on this wing, and divided, part following the cable and part jumping to the telephone line. If there had been another ground-connection for this portion of the system probably no damage would have occurred.

All ground-rods should go deep enough to be in perpetual moisture. In Michigan where rods are subject to insurance inspection it is insisted that ground-rods must go at least eight feet in the earth, and many are sunk ten feet.

Importance of Proper Grounding.

Here let a note of warning be sounded to everyone who is having his buildings rodded: Be present and *see* the ground-rods put down. Know for yourself that the rods are actually down eight feet or more. Do not take anybody's say-so on this point. Lightning-rod men, as a class, are as honest as any other class of the community, but an odd one is unscrupulous and will "scamp" the job if possible. We have a record of a case where the rodding agent instead of putting the cable eight feet straight down in the earth coiled it up and buried it in a small hole in dry earth, and the barn was burned by lightning the very day it was rodded. Nothing could be more dangerous. When electric power companies want to prevent the lightning charge from coming in on the line wires and damaging their machinery they make a "choke"-coil of several turns of the wire just inside the station and beside the line put a ground-wire separated from the line by a short air-gap. When the lightning charge follows the line to the station the "choke"-coil makes it so difficult for the sudden current to pass that it jumps the air-gap to the ground-wire in preference and thus escapes to the earth. Now the coil at the foot of the lightning rod acts just in the same way. It chokes the current back and makes it take some other path, down through the building, probably firing the building on the way. In a coil self-induction is very high, hence the choking effect.

Consequently, let us say again, look well to the groundings. They are probably the most vital part of the system. *See the ground-rods put in.*

3. *Systems.*—The cable beginning at one ground-rod should extend up the corner, make a gradual turn at the eaves, go up the edge of the roof to the peak, along the peak to the other end, down the edge of the roof to the eave, and down the corner to the other ground. All turns should be rounded rather than angular.

All the cables on a building should be connected in one system. Sometimes it is found that on an L-, T- or U-shaped building, for instance, the rods on the one part are not connected with those on the other. Numerous instances are reported where damage has occurred between these two systems, the lightning striking the one system and part of the current jumping across to the other. Consequently, divided systems should be scrupulously avoided. When a cupola is encountered the cable should go around rather than over it, the point on the cupola being connected to the cable below.

As the cables near the ground are often subject to injury by stock, implements, etc., they should be protected by wooden strips fastened together in suitable form and nailed over the cable from the ground up to a height of six or eight feet.

NO INSULATORS TO BE USED.

4. *Attachment.—Insulators should not be used.* The rods should be in metallic connection with the building. This method of attachment is in direct opposition to that practised when lightning rods were first used. It was then considered desirable to insulate the rods from the building by glass or earthenware insulators. As a thunderstorm approaches the entire outer surface of the building is charged with electricity, and by having the rods in metallic connection with the building the charge is conducted to the rods and thence to the points where it leaks off and neutralizes the opposite charge existing in the cloud.

Several methods are used for fastening the cable to the building. Some companies use copper nails, which are driven right through the cable. Others use staples, others clips which hold the cable tight to the building, and some use a clip which holds the cable out about an inch from the building, the claim for the last method being that with the rod standing out chaff, straw, and the like would not so readily collect between the rod and building, and thus a danger of fire is avoided in case strokes occur. At first the writer rather thought this point well taken, but after finding an efficiency of 999 cases out of 1,000 in Michigan where the rods were practically all fastened close to the building, and the three small damages that did occur all being due to other causes, we concluded that it would be rather difficult to secure any higher efficiency. While we say this, we see no particular objection to having the rods stand out from the building, unless it might be that the rod is more exposed and thus more subject to injury.

POINTS TWENTY TO THIRTY FEET APART.

5. *Points.*—At intervals along the cable on the ridge there should be placed uprights with points that will not corrode. These uprights should be firmly fastened to the cable. There is no absolute law as to the distance apart at which these points should be placed, but a rule frequently used as an approximate guide is that the distance between them shall not be greater than twice the combined height of the two uprights. By this rule if the points were five feet in height they would be placed about twenty feet apart. There is, however, a tendency among practical lightning-rod men to use shorter and shorter uprights, some as short as 26 inches, but with these short uprights the points are still placed twenty to thirty feet apart. Copper tubes of suitable size and weighing the same per foot as the rods make the best uprights. They are supported by standards in the form of tripods, thus being strongly braced.

The experiments with the little electrical machine have shown us that the flash selects angles and prominences, and we know that lightning shows the same preference in this respect. Consequently points should be placed near each end of the ridge, on or beside chimneys, and on cupolas and dormers. Those on or beside chimneys or cupolas should project above them at least eighteen inches.

On the uprights ornaments of one kind or another, such as bright balls and weather vanes are frequently placed. Scientifically and according to at least three manufacturers of rods in Ontario, the former are of no use in telling whether the building has been struck by lightning, as is sometimes stated by agents. The vanes are a weakness if they rotate on the upright, for in constantly oscillating with the wind they in time wear the uprights until they bend and sometimes even break off at the vane. Both balls and vanes add to the appearance, but the latter had better be dispensed with, unless they rotate on a stationary collar. When strong tubes are used as uprights there is no serious objection to the balls, for they are not likely to catch enough wind to do any damage.

METALLIC BODIES SHOULD BE CONNECTED IN THE SYSTEM

6. *Metallic Parts of Structure.*—Lightning-rod companies here differ considerably in practice. Some connect all metallic portions of the structure to the rods, others do not. The former is undoubtedly the better practice. If the metal body is a long one, like a steel track, roof-gutter, or eave-trough and conductor pipe, both ends of it should be connected to the rods, or one end to the rod and the other grounded. Where buildings are already rodded, but the rod runs straight from the peak to the ground, leaving the eave-troughs and conductor pipes unconnected and ungrounded, this could easily be remedied by connecting one end to the cable and grounding the other end by a new ground-rod.

Telephones should always be protected by "lightning arresters." This we believe is always looked after by the telephone companies.

SOME CASES OF DEFECTIVE RODDING.

In this relation we wish to refer to an occurrence that took place in the township of Adelaide, County of Middlesex, during the past summer. Two barns belonging to Mr. Harold Currie were burned on June 6th, 1913. It was reported to us that they were rodded. We wrote to Mr. Currie at once. Here is his answer:

> "Yours of August 25th to hand, and in reply wish to say that my two barns were burned by lightning on the night of June 6th, 1913. They were rodded, and the rods were in first-class condition with no dead ends. In fact, the Inspector of Insurance Company examined the rod after the fire, and pronounced it in good condition and there was not a break in it. Then, since receiving your letter, I pulled the end out of the ground to measure the length, and it was nine feet in the ground. Mr. ———, of ———, put the rods on five years ago. The barns were new and were upon cement and brick walls. Of course, one was struck and the other caught from it. As to the name of the rod I can't tell you, but it was a round cable of coppered wire. The barn that was struck was 56 ft. x 46 ft., and had three points on it, and the rod ran down at the north end only. This barn was also covered with Galvanized Iron Shingles, the Oshawa shingle, manufactured by the Pedlar People, and was troughed all to one corner where the conductor pipe ran down into the 4-inch tile which carried the water away. Now, Sir, I wish to state a few facts. I had in those buildings (at the time of the fire) a number of valuable race horses, and had just come from the barn and was standing at the door of the house watching the storm, and saw the lightning come down but could not tell whether or not it hit the barn, as it dazzled my eyes and staggered me back against the door. When I got my sight again there was no sign of fire, so I went into the house to go to bed, and in passing a window saw what looked like a lantern in the southwest corner of the barn. I am satisfied that the rods were not touched, but that the lightning went down the conductor pipe, which, by the way, had a length broken out by the wind on Good Friday, just at the top of the brick wall, and as this mow was filled with straw and summer bedding for the horses, it caught fire and burned fiercely. I am of the opinion that if the pipe had not been broken I would have had no fire. I was insured in the London Mutual Co. I have noticed since the number of barns that have the conductor pipe come down just to the bottom of the timber, which is a trap, for if lightning ever comes down that pipe it will surely go into the barn at that point.
>
> "If there is anything that I have not made clear to you I will be pleased to answer any further questions."

Our reply to this letter was in part as follows:

> "We are in receipt of yours of August 25th re the rods on your barns that were burned. We note that only one barn was struck, and the second caught from the first. Judging from your letter the rod ran down the gable from the peak at the north end, and not from the eaves. Is this correct? We also conclude that the cable ran along the peak of the barn, and that there were three uprights from this cable. Is this correct? Or having a metal roof, was any cable used except at the ground-rod?
>
> "Did you examine the points or were they destroyed? Were any of them fused? We should be glad to have sample of the rods, also one of the points, a fused one if any were fused.
>
> "We note that the rods were in good condition, but the system of rodding is very defective indeed. In the first place, there should have been at least two ground-rods. In the second place, with a metal roof, the cable *must* leave the roof at the eaves, because in a metal roof resistance and self-induction are both so small that the obstruction offered by the roof, and the air-gap at the corners may be less than that of a long cable from the peak, especially if air-gap is short on account of conductor-pipe, and, thirdly, one of the ground-rods should have been at the south-west corner, so that the conductor-pipe could have been connected to the rod. If the one ground-rod that was in had been at the south-west corner, and the conductor-pipe connected, as suggested, we are satisfied that your barn would have been saved.
>
> "We are not sure that you are right in concluding that the rods were not touched. We know that whenever electricity has two nearly equal paths open to it, part goes one path and part the other. Probably part of the charge went down the rod and part down the conductor-pipe. It would appear that the bolt must have been a very violent one."
>
> "The writer has just come back from Iowa and Michigan, where he has been investigating the subject of protection against lightning, and without going into detail, we are going to give you one or two facts learned on the trip. In the State of Michigan there are two mutual companies which insure buildings all over the State. One insures only rodded buildings, we shall call it the Protected Company. The other insures both rodded and unrodded, we shall call it the Unprotected Company, but it keeps its rodded buildings in a separate class, and this class is assessed for its own losses. Both these companies are very particular in having the buildings rodded properly. Neither one of them would have accepted your building in their rodded class, considering the rodding defective in the respects pointed out above."

Here is another illustration that shows the need of connecting metallic bodies to the rods: A barn was rodded, the cable passed down the end to the ground. Inside at a distance of about three or four feet was the end of a water-pipe. Under the water-pipe stood a cow. A bolt of lightning struck the rod and the cow was killed. Now what happened was probably this: Part of the charge side-flashed through the wall to the water-pipe, and from that to the cow.

The second damage suffered by the Protected Mutual is described by the Secretary in the following words: "The other damage in 1912 was on account of a large galvanized storage tank in the attic of the house, only a few feet below the rod, which ran along the ridge of the building. This tank was thoroughly grounded with gas-pipe, so that the lightning split and part of it followed the rafter down and jumped across to the tank. Had the tank been connected with the rod, we are satisfied this damage would not have occurred."

In nearly all cases where damage is done to rodded buildings it is found that the current has jumped an air-gap. The obvious remedy is to avoid possible air-gaps. If the end of that water-pipe had been connected to the cable outside the barn and the other end connected to the other "ground" the cow above referred to would doubtless have been perfectly safe.

On page 32 attention was drawn to the great importance of having the groundings properly made. The connecting of metallic parts of the structure to the systems is equally important. After the correspondence with Mr. Currie we observed a large number of barns where the gutters, eave-troughs and conductor-pipes were not connected in the system. We are satisfied this is one reason why the efficiency of rods in Ontario is only 92 to 94.5 per cent., while in Iowa it is 98.7

per cent., and in Michigan, under inspection, 99.9 per cent. In those two states they are much ahead of us in the art and science of rodding buildings.

Metallic roofs should be grounded at two *corners* at least, the cable being stapled or soldered to the metal roof at the eaves, and either points or sharp-edged ridge-boards should be used. It is not necessary to run the cable up to and along the peak. Simply fasten the uprights to the metal roof at the ridge. The metal roof of cupolas should be connected to the main roof. Conductor pipes from metallic roofs should be grounded. Under no circumstances should metal roofs be grounded from the peak, for if a stroke occurs low down on the roof the current will not travel upward to the peak, but will leave the roof at the lowest point.

A windmill on a barn should be connected to the cable, also the bottom end of the shaft either connected to the cable or separately grounded to perpetual moisture.

WIRE FENCES.

7. *Fences.*—A wire fence is not properly grounded, unless in large fields there is a grounding at least every twenty rods, though closer together is better, and in barn yards or small yards where cattle are herded, at every corner. Where fences are connected with a building there should be a grounding at the first post from the building, and moreover the ground-rod from the building should be connected with the fence. A fence grounding should consist of a rod or cable equal to three No. 12 wires or one No. 9 wire stapled over or connected with each lateral wire of the fence, and extending at least three feet into the ground. If the ground wires are allowed to project a few inches above the fence, strokes are prevented in the vicinity just as by the points on a building. The fence groundings should be made of the same material as the fence wires.

8. *Shade Trees.*—Where there are a *few* trees under which stock gather for shade it would be both wise and feasible to rod the trees. The same principles apply here as in general rodding.

CONCLUSION.

From the days of Franklin to the present time the value of lightning rods has been an undetermined quantity, physicists of course holding that they must be highly beneficial, the greater mass of the people, however, retaining an open mind, while some accepting the teachings of science rodded their buildings; and still others counted absurd the idea that rods and points could have any worth in preventing damage to buildings by lightning. From time to time practical data have appeared giving one side of a comparison, but lacking the other—*e.g.*, "A certain insurance company over a period of years has never paid a dollar of insurance on a rodded building damaged by lightning," but they were unable to tell what percentage of their risks were rodded, so no definite comparison could be made.

Now, however, the Department of Agriculture is pleased to present the data herein contained, giving complete comparisons, which prove unmistakably that lightning rods properly installed are almost absolute protection against lightning.

These practical results the farmers of Ontario can appreciate better than scientific statements, and with these at hand the Department can safely recommend the rodding of farm buildings in accordance with directions above given.

SUMMARY OF DIRECTIONS FOR RODDING.

The writer has omitted drawings purporting to show how to rod buildings. The proper method can only be decided after a close examination of each building in question, for then alone can one intelligently apply the principles already dealt with.

For convenient reference the directions for proper rodding are repeated without any of the explanations.

1. Kind of Rods.

Material—Copper, aluminum or galvanized iron, preferably the first because of durability. Aluminum may prove equally durable.

Combinations are not advised, because not as durable as single-metal rods.

Weight—Copper—At least 3 ounces per foot.
Aluminum—At least 2¼ ounces per foot.
Steel (iron)—At least 4½ ounces per foot.

Form—Any form that will give durability and convenience of installation.

2. Ground-connections.

Depth—Down to perpetual moisture. At least 8 feet deep.

Number—On an oblong building, at least two.
On an L- or T-shaped building, at least three.
On a U-Shaped building, at least four.

Location—Preferably at opposite corners, though this may be modified to avoid manure, or to go down near conductor-pipe or other metallic portion of the structure. If conductor-pipe is on the side of the building the ground rods should be at the corners as above stated, the eave-troughs connected to it, and then the conductor pipe also grounded.

Ground-rods should not be bunched, but should be distributed as well as possible.

Method—In deep soil drill a hole at least eight feet deep and run cable down.

In shallow soil, attach cable to metallic ground-plate, which is put down as deep in soil as possible; or run it into a well or a stream or a crevice in the rock. If none of these are feasible, put cable as deep as possible and lay large, flat stone over it.

Caution—Be present, and see that ground-connections are properly made. The rest of the system may be inspected at any time, but the groundings only when they are being put down.

3. Systems.

Run cable from ground up corner to eave, thence to ridge, along ridge to other end, thence down to eave, thence to other ground, making a complete circuit.

All cables should be connected in one system.

No stubs or dead ends should be left ungrounded.

Caution—Cables should be protected from ground six or eight feet up by nailing boards around them.

4. Attachment.

Fasten cable to barn with nails, staples, clips or metal "dispersers."
Caution—Do not use insulators.

5. Points.

Number—20 to 30 feet apart.

Location—On ridge, first ones not over five feet from end.
On or beside chimneys or cupolas.
On dormers. Also on silos.

Height—Four to five feet, except those on or beside chimneys, cupolas or similar prominences; these must extend at least eighteen inches above the highest part.

Form—Strong tubes, of same weight and material as rods.

6. Metallic Portions of Structure.

Roof-gutters—Top connected to rod, and bottom grounded.
Eave-troughs and Conductor-pipes—Free end of eave-troughs connected to rod, and conductor pipe grounded.
Hay-fork Track—Both ends connected to rod.
Tanks—Connected to rod above, grounded below.
Windmill—Connected to rod above, shaft grounded below.
Metallic Roof—Grounded at two or four corners, not from peak under any consideration.
Points should be used on the ridge and other prominences.

7. Wire Fences.

In field—A grounding at least every twenty rods.
In yards—At the four corners.
At building—Ground at first post from building.
Weight of Groundings—Equal to three No. 12 or one No. 9 wire.
How Made—Stapled on posts in contact with all wires of fence, and extending at least three feet in the ground, and projecting above fence.

8. Shade Trees—Protect where feasible.

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